ACTA STEREOL 1994; 13/2: 343-348
PROC 6ECS PRAGUE, 1993
ORIGINAL SCIENTIFIC PAPER

EFFECT OF MODIFICATION WITH ALKALINE EARTH METALS UPON THE MORPHOLOGICAL PARAMETERS OF NON-METALLIC INCLUSIONS

Teresa LIS

Silesian University of Technology
Chair of Extraction Metallurgy
Krasińskiego 8, PL 40-019, KATOWICE, POLAND

ABSTRACT

The non-metallic inclusions are the natural components of the microstructure of steel and alloys, and usually exhibit some directional arrangement of individual, flake-like or lamellar particles. In the eighties some attempts was made to develop methods for description of the lamellar microstructure with individual stereological parameters or some sets of them. These non-metallic inclusions were studied in this research-work. The main purpose of the studies was to find out what was the effect of treatment of steel with calcium and magnesium alloys upon the morphology of non-metallic inclusions in the steel.

Application of methods of quantitative metallography to evaluation of non-metallic inclusions content in steel makes it possible to do it more correctly and objectively. The carried out quantitative analysis of non-metallic inclusions leads to a conclusion that the treatment of 45 steel grade with calcium and magnesium alloys reduces area fraction of inclusions, especially as far as the plastic inclusions are concerned, and reduces also the number of inclusions particles.

Key words: morphological parameters, non-metallic inclusions, quantitative metallography.

INTRODUCTION

Reduction of non-metallic inclusion content, that may affect mechanical and technological properties, as well as the susceptibility to environmental impact etc., is becoming more and more frequently indicated as one of numerous requirements relevant to the quality of steel products. The non-metallic inclusions are the natural components of the microstructure of steel and alloys, and usually exhibit some directional arrangement of individual, flake-like or lamellar particles. In the eighties some attempts was made to develop methods for description of the lamellar microstructure with individual stereological parameters or some sets of them (Miyata et al.,1974).

When selecting the reagents suitable for the deoxidation of steel one should take into consideration such features as: the behaviour of the reaction products in the liquid metal, their easy removal, as well as the type and shape of inclusion particles which may appear in the steel. This may affect the mechanical properties of the steel what leads to the

commonly accepted opinion (Kühnelt et al.,1981; Pickering, 1990) that the control of the character of inclusions together with appropriate level of deoxidation and desulphurizing is the best economically justified way for the quality steel production.
These non-metallic inclusion were studied in this research-work. The main purpose of the studies was to find out what was the effect of treatment of steel with calcium and magnesium alloys upon the morphology of non-metallic inclusions in the steel.

EXPERIMENTAL AND RESULTS

The expertise acquired so far has shown that the construction steels are particularly prone to anisotrophy of their mechanical properties. A construction steel of 45 grade (composition: 0.46% C, 0.65% Mn, 0.24% Si, 0.043% S, 0.016% Al, 0.0063% O, 0.0001% Ca, 0.07% Cr, 0.10% Ni, 0.10% Cu, 0.02% Nb) was selected for the studies. For technological reasons (an increase of calcium and magnesium solubility in iron at the presence of silicon, aluminum and nickel) a number of two- and three-component modifying alloys were prepared, having the following chemical composition:

CaSiAl:	20% Ca	50% Si	5.7% Al
CaSiMn:	11.8%	Ca17% Si	10.5% Mn
NiMg:	14% Mg		

The steel was treated with CaSiAl, CaSiMn and NiMg alloys in an induction vacuum furnace VSG-02 (Balzers) at 1863 ± 10K under argon atmosphere of 1520 hPa.
X-ray microanalysis of the inclusions was carried out with JSM-35 and JXA 50A microprobes. The inclusions in the steels can be described in general as sulfo-oxides of complex chemical composition - Fig. 1 (Lis et al.,1992).

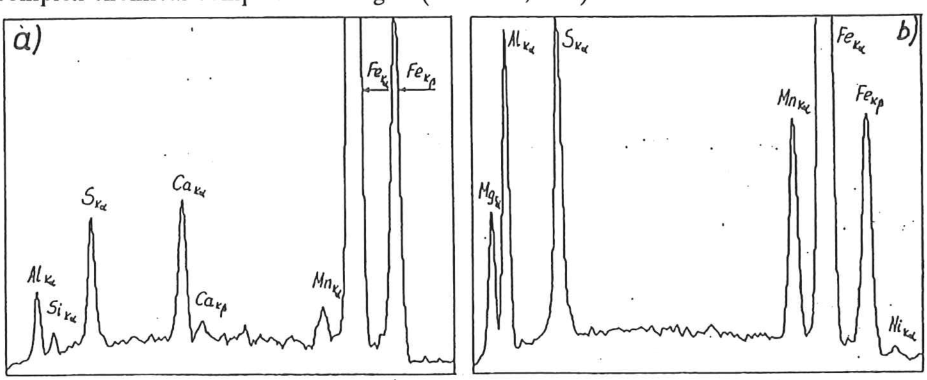

Fig.1. Chemical composition spectra of a sulfo-oxide inclusion in steel treated with a) calcium, b) magnesium.

Therefore, the tradition classification of inclusions into separate groups of oxides and sulfides seems to be no longer justified, and should be replaced with a new one, including plastic and non-plastic inclusions. The Feret's diameters ratio F_y/F_x can be the criterion for the classification. Stereological analysis of the inclusions was carried out with a Morphopericolor automatic image analyzer, combined with a Neophot 32 optical microscope. In each metallographical cross-section the analysis of non-metallic inclusions was performed in 45 fields. Total area of the analysed cross-section was 2 349 mm^2. The following stereological parameters of the inclusions were evaluated:

- number of inclusions per unit surface (N_A) and their area fraction (A_A) - fig.2 and 3;
- distribution of the inclusion number versus their area (fig.4), their Feret's diameter ratio (fig.5) and the shape factor (fig.6);
- distribution of the area fraction A_A occupied by the inclusions for various plane section area A (fig.7), versus their Feret's diameter ratio (fig.8) and the shape factor (fig.9).

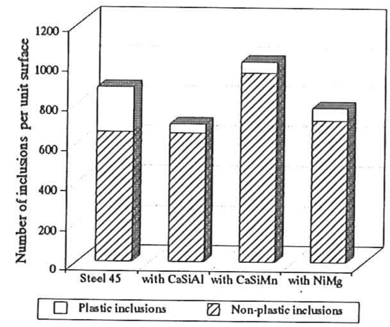

Fig.2. Number of non-metallic inclusions per unit surface in 45 steel before and after treatment with CaSiAl, CaSiMn and NiMg alloys.

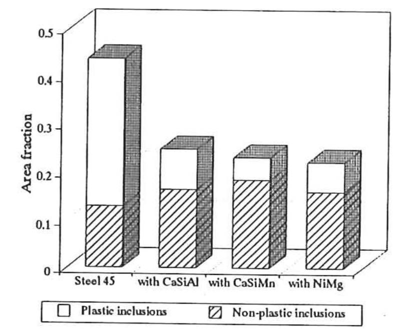

Fig.3. Non-metallic inclusion area fraction per unit surface in 45 steel before and after treatment with CaSiAl, CaSiMn and NiMg alloys.

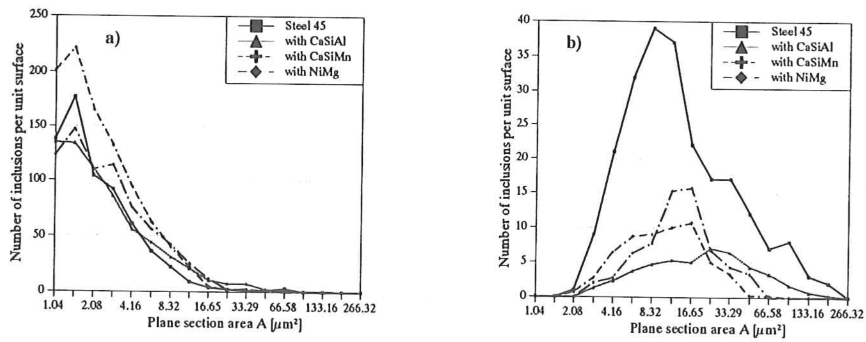

Fig.4. Distribution of the inclusion number versus their plane section area A a) non-plastic inclusions, b) plastic inclusions.

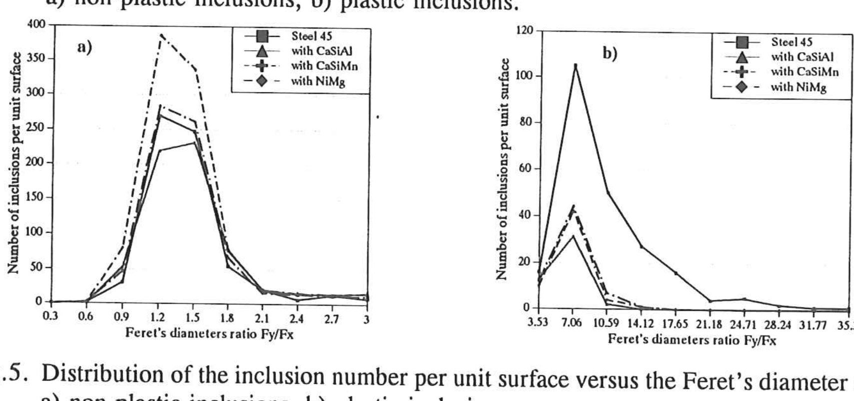

Fig.5. Distribution of the inclusion number per unit surface versus the Feret's diameter ratio a) non-plastic inclusions, b) plastic inclusions.

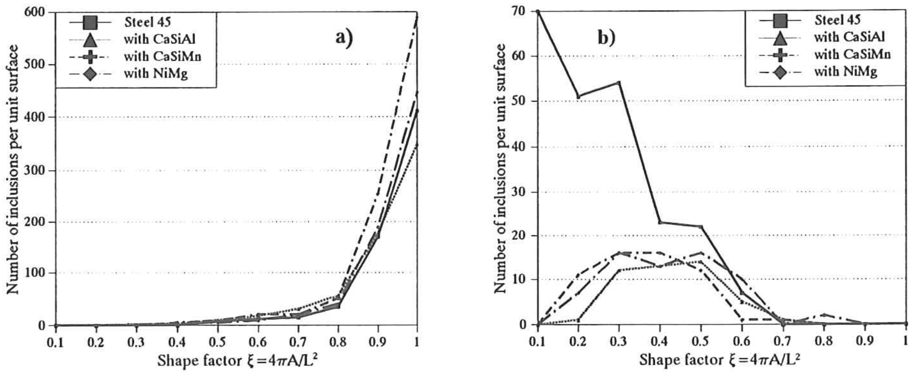

Fig.6. Distribution of the inclusion number per unit surface versus their shape factor a) non-plastic inclusions, b) plastic inclusions.

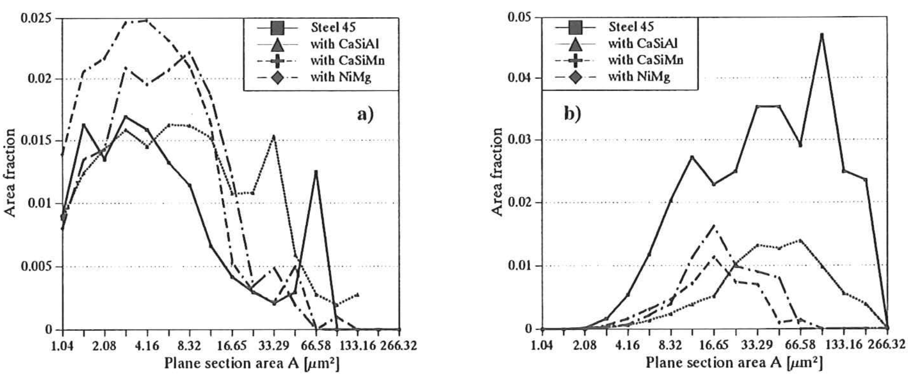

Fig.7. Distribution of the inclusion area fraction versus their plane section area A a) non-plastic inclusions, b) plastic inclusions.

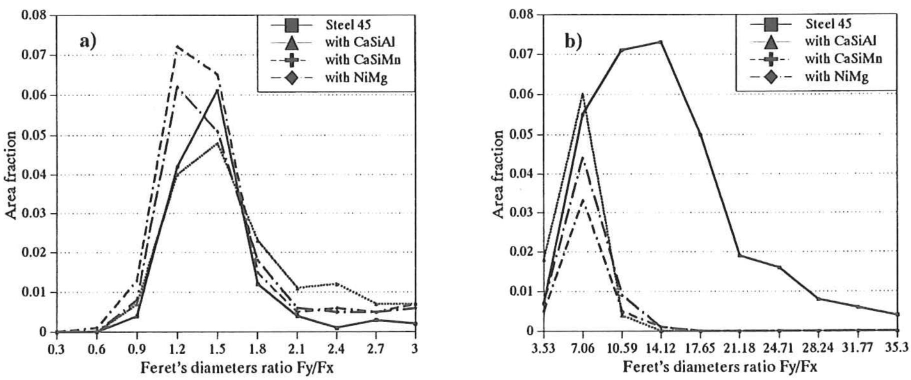

Fig.8. Distribution of the inclusion area fraction versus Feret's diameter ratio a) non-plastic inclusions, b) plastic inclusions.

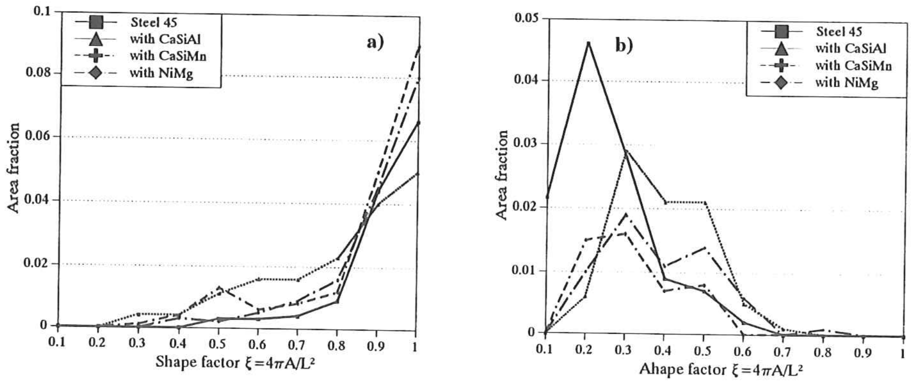

Fig.9. Distribution of the inclusion area fraction versus their shape factor a) non-plastic inclusions, b) plastic inclusions.

DISCUSSION AND CONCLUSIONS

The carried out quantitative analysis of non-metallic inclusion leads to a conclusion that the treatment of 45 steel grade with calcium and magnesium alloys reduces the area fraction of inclusions, especially as far as the plastic inclusions are concerned (fig.3), and reduces also the number of inclusion particles (fig.2). Above all, area fraction of large plastic inclusion ($> 60\ \mu m^2$) has decreased (fig.7b). The presented results indicate also some refinement of inclusions in 45 steel after treatment with the mentioned alloys. Elongation of the residual plastic inclusions is considerably lower which implies their reduced deformability in comparison with untreated 45 steel (fig.5b, 7b). This conclusion can be confirmed by the increase of the shape factor value of plastic inclusions in the treated alloys (fig.6b, 9b, 10).

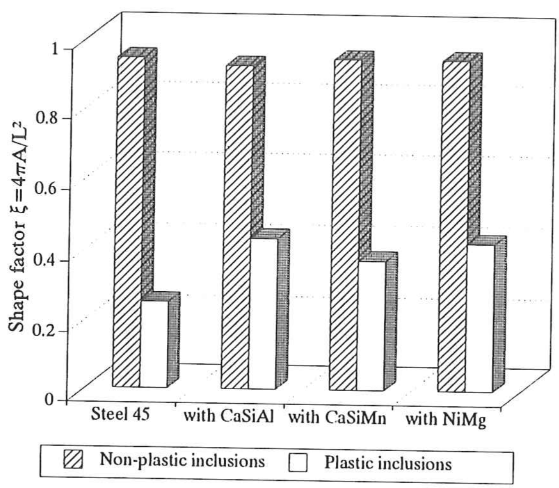

Fig.10. Mean value of the shape fector odf non-metallic inclusions in 45 steel before and after treatment with alkaline earths metals.

The results of the investigations performed justify a statement that the treatment of aluminum-deoxidized steels with calcium and magnesium alloys affects the non-metallic inclusions beneficially making them globular and reducing their deformability in plastic working. And in particular:

- the area fraction (A_A) of the inclusions decreases while the area fraction of those non-plastic is elevated;
- the inclusion elongation after plastic working decreases which demonstrates in the Feret's diameters ratio F_y/F_x;
- the inclusions become more globular in shape, as indicated by the increase of the shape factor $\xi = 4\pi A/L^2$.

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